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AUGUST 1979

PROCEEDINGS OF THE 30th ANNUAL TUNA CONFERENCE

by

Gary T. Sakagawa, Chairman

ADMINISTRATIVE REPORT LJ-79-44

NOTICE

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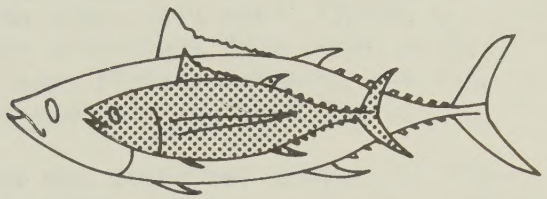
Proceedings of the

30th Annual Tuna Conference



UNIT STOCK MANAGEMENT OF HIGHLY MIGRATORY SPECIES

Is it an imperative ?

May 13 - 16, 1979

Gary T. Sakagawa, Chairman
Southwest Fisheries Center, NMFS
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PREFACE

The Tuna Conference is an annual event jointly sponsored by the California Department of Fish and Game, Long Beach, California, the Inter-American Tropical Tuna Commission, La Jolla, California, and the National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, California. It was first organized in 1949 as an informal meeting for exchange of scientific information and research ideas on tunas among North American scientists. Through the years this basic format has been followed and expanded upon to include scientists from other parts of the world, non-scientists involved in tuna fishery matters, and discussions on billfishes, other tuna-like species and porpoise involved in tuna fishing.

The 30th Conference was organized around the theme, "Unit stock management of highly migratory species -- is it an imperative?" It was held at the University of California Conference Center, Lake Arrowhead, California from May 13 to 16, 1979. Fifty-nine persons attended and participated in discussions on stock identification techniques, status and potential yield from tuna stocks, and management and the unit stock concept. Contained in this Proceedings are abstracts of papers presented at this Conference and summaries by session moderators of the discussions.

Numerous individuals assisted in the planning, arranging and execution of the Conference. The Conference would not have been a success without their assistance, devotion and dedication to the task. In particular, I would like to acknowledge the assistance of Robin Allen, Frank Alverson and John Calaprice for advice and for serving as moderators of the sessions; James Joseph for advice and assistance in organizing the Conference; and Ronald Rinaldo for assistance in all the details that go into organizing a conference. Lastly, to all the participants, my appreciation for contributing to the success of the Conference.

The elected chairman for the 31st Conference is Alex Wild.

Gary T. Sakagawa, Chairman
La Jolla, California
August 1979

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UNIT STOCK MANAGEMENT OF HIGHLY MIGRATORY SPECIES - Is It an Imperative?

Opening Remarks

by

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In the past few years, there has been a series of events that altered the existing design of management of tunas and billfishes. The design has been that highly migratory species, because they undertake long migrations and are exploited by several nations, should be managed on a coordinated, international basis rather than on a splintered, national basis. The series of events is associated with coastal states extending their sovereignty and jurisdiction over the living resources within 200 miles of their coast. These events explicitly or implicitly have challenged the widely accepted concept in fishery science of "unit stock management", or coordinated management of a stock throughout its distributional range, wherever it is caught. Some events in point are:

1. The United Nations Law of the Sea Conferences have demonstrated that the concept of coastal nation control over fishery resources within 200 miles of the coast is widely accepted.

2. Enactment by the United States of the Fishery Conservation and Management Act (FCMA) of 1976. Although this act exempts the highly migratory tunas from unilateral U.S. management, it does not exempt the highly migratory billfishes.

3. In November 1977, Mexico declared that the Inter-American Tropical Tuna Convention (IATTC) is inconsistent with her 200-mile jurisdictional requirements and served notice to withdraw from the IATTC in November 1978 and manage the highly migratory species within her zone according to Mexican law.

4. Costa Rica likewise claimed that the IATTC is inconsistent with her 200-mile law and withdrew from the IATTC, effective April 1979.

5. In November 1977, several south Pacific countries began organizing the South Pacific Regional Fisheries Organization to manage highly migratory tunas in the 200-mile zone of the member countries.

It appears timely, therefore, that at this 30th Conference we examine and

discuss the appropriateness of the unit stock management concept for the highly migratory species and whether this concept, if appropriate, can be modified to accomodate the changing political setting. The agenda of this 30th Conference has been structured to allow for full discussion of the issues.

In Session 1, old and new techniques for identifying stocks will be discussed. I'm sure that various definitions of unit stock will be used by the speakers. For clarity, I might outline here the generic definitions for unit stock:

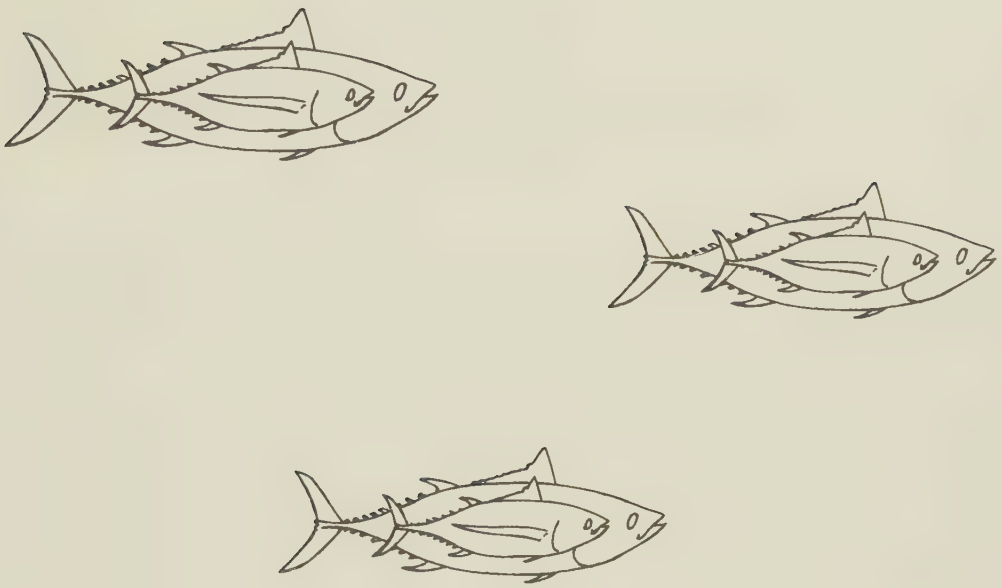
1. A genetic unit. A population or portion of population whose members are genetically alike and self-sustaining, i.e., members segregate at spawning time.

2. A management unit. A group whose members have the same growth pattern and mortality rates and are fished in the same area by the same gear.

In Session II, we will hear reports on the condition of some tuna, billfish, and dolphin stocks. Currently, about 2.2 million metric tons (1975 statistics) of tuna and tuna-like fishes are caught from all oceans and about 61,000 dolphins (1977 estimate) are killed incidentally to tuna fishing in the eastern tropical Pacific. About 41%, or 1.0 million metric tons of this world catch are yellowfin tuna, bigeye tuna, southern bluefin tuna, northern bluefin tuna, and albacore. Many of the stocks appear to be fully exploited or in a few cases, even overexploited. It is important, therefore, that the status and future potential of these stocks and others be known if there is to be effective management of the stocks and the fisheries that depend on them.

Finally, in Session III, the views on management of highly migratory species from a scientist's, a policy administrator's, and a tuna industry representative's prospective will be presented, and the events that are challenging the established tuna management design discussed. The discussion will include comments on the evolving management regime in the eastern Pacific, the United States attempts to manage billfishes for conservation purposes under the FCMA, and the management of northern bluefin tuna of the Atlantic Ocean under stock structure uncertainty.

I hope that the program for this 30th Tuna Conference is successful in being intellectually stimulating and in providing useful information to all of us. The Conference is structured as a forum for informal exchange of scientific information and ideas; consequently, you are encouraged to ask the speakers questions and to participate in the discussions.



STOCK IDENTIFICATION TECHNIQUES

John R. Calaprice, Convenor

TUNAS AND BILLFISHES, AND EPIPELAGIC RESOURCE AND ITS PROBLEMS: AN OVERVIEW

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Tunas and billfishes are members of the families Scombridae, Istiophoridae, and Xiphiidae. These epipelagic fishes range throughout the tropical and temperate waters of the world oceans. Many species considered here are cosmopolitan. Tunas and billfishes through their highly specialized anatomy and physiology are remarkably adapted for their environment. Their reproductive capability and growth are prodigious. The fecundity of tunas is about 100,000 eggs per kilogram of body weight. Billfishes are nearly as fecund. Tunas and billfishes start their life as tiny larvae. As larvae and juveniles they are preyed upon by many marine animals and several oceanic birds. The mortality among the earlier life stages of tunas and billfishes must be of staggering proportions. Tunas and billfishes become apex predators only upon becoming adults. The largest species of tuna, Thunnus thynnus, will increase its hatching weight approximately one billion (10^9) times before it attains maximum size. Many species of tunas and billfishes undertake extensive migrations amounting in some cases not only to transoceanic but even interoceanic journeys. Although the world catches of tunas and billfishes are not the largest by weight, they are among the most valuable commercial species in the world fishery. Tunas and billfishes are also important as a recreational resource in some parts of the world. The Pacific catches of tunas and billfishes amount to about 70% of the global landings of these fishes. Harvesting of these species is accomplished by a variety of fishing methods. Many of the vessels engaged in the fishery for these species are capable of operating in any of the world oceans, and indeed some of the vessels fish in more than one ocean. Therefore, any conservation measures applied to these fishes must take into account the highly migratory habits of the fish as well as the high mobility of the fleet engaged in the fishery for these species. Many nations are involved in the fishery but only a handful of nations reap the bulk of the global harvest of these species.

Over the last few decades world consumption of tunas and billfishes has been increasing. The newly established 200-mile economic zones of many nations exacerbates the problem of the conservation and management of these species since tunas and billfishes are a resource which is highly migratory and which is readily harvested in truly international waters. Taking into consideration all these factors it is concluded that meaningful management of this resource can be accomplished only through international cooperation.

ECTOPARASITES OF EASTERN AND WESTERN ATLANTIC BLUEFIN TUNAS

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Ectoparasites of Atlantic bluefin tuna, Thunnus thynnus, were collected from fish captured in the western Atlantic from Cozumel Island and the Gulf of Mexico northward and eastward to the Gulf of Maine. Parasitic infestations were correlated with the ages of the host fish. Some fish of Mediterranean origin were examined also.

Two species of ectoparasites, the trematode Nasicola klawei and the copepod Elytrophora brachyptera, have interesting host distributions. The trematode is acquired in "tropical" waters of the western Atlantic in the spring and summer months, while the copepod appears to be acquired in "temperate" waters of the eastern Atlantic during the fall and winter months. This permits an insight to the biology of the sub-adult bluefin tuna, enabling one to distinguish, among fish captured in the western Atlantic, those which had been born in the western Atlantic and those born elsewhere.

TAGGING STUDIES FOR STOCK IDENTIFICATION

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Marr (1957) defined a subpopulation as "a fraction of a population that is itself genetically self-sustaining" and a stock as "a population or a portion of a population, all members of which are characterized by similarities which are not heritable, but are induced by the environment." The fish present in a given area-time stratum may consist of several subpopulations which may or may not be distinguishable by the methods presently available, or they may consist of a single subpopulation which may or may not be divisible into several stocks by environmentally-caused differences.

The term "stock identification", however, is used in a more general sense in reference to studies of intermingling of fish of the same species. For example, if fish occur in area-time strata A and B it is of interest to know (1) if the fish of these two strata intermingle at any time and (2) if at any time the fish of Stratum A or B separate into more than one group. Also, it is useful to be able to identify fish of any stock wherever and whenever they might be found.

Questions regarding stock identification cannot usually be resolved by tagging alone, but tagging data, combined with other information, can be useful for this purpose. Most of what is known regarding stock identification of tunas and billfishes has come from tagging data. It has been shown that albacore, northern and southern bluefin, and skipjack make transoceanic migrations, and that some yellowfin migrate more than 2,000 miles. Accordingly, in most cases the fisheries of different areas are not exploiting different stocks.

A model for the life history of northern bluefin tuna in the Pacific Ocean is presented to show how tagging data and other information can be combined to better understand the stock structure of this species.

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DISCRIMINATION OF APPROPRIATE STOCKS USING ELECTROPHORETIC TECHNIQUES: ADVANTAGES AND DISADVANTAGES

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The notion of unique fish stocks inhabiting certain geographic regions and thereby maintaining a species as a collection of genetically isolated populations has immense intuitive appeal to fisheries managers. Isolated populations are also a non-intuitive necessity in management modeling technology, since the output variance of any model is controlled by the boundary conditions of the input data.

Biochemical genetics appeared in the nineteen sixties to be an enormously powerful taxonomic tool that could establish isolated stock boundaries with a high degree of resolution.

For example Payne, Child and Forrest (1971) established two races of Atlantic salmon on the basis of a rare transferring allele frequency change of the order of 0.0165 to 0.0018. The biological justification for using this very small, albeit significant, difference lay in their statement.

"...the rare Tf_2....phenotype ratio of 466:66:2 agrees very closely with the 467:65:2 expected ratio of a Hardy-Weinberg-Castle equilibrium."

The implication being that as the samples were in Hardy-Weinberg equilibrium the polymorphism was not under the selective control and did not vary with time; therefore, any differences in allele frequency that are greater than that due to chance must be an indication of genetic isolation, hence races.

Examination of six species of New Zealand fishes at the phosphoglucomutase and glucose phosphate isomerase loci for genetically isolated stocks (Gauldie and Johnson, 1979) led to the following dilemma:

If one assumes that any difference greater than chance in allele frequencies can be used to establish stock structures, then all such structures are functions of sample size, that is to say, artifacts. This is not a problem if the source of variation in allele frequency is simply regarded as physiological noise (Kimura and Ohta, 1971). Then the observed differences <u>are</u> artifacts and can be analyzed as such.

On this assumption, analysis of significant differences in allele frequencies between stations in Hardy-Weinberg equilibrium for all species showed a number of stock boundaries in New Zealand waters. Furthermore, many of these boundaries were shared by more than one species, indicating that some

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sort of physical isolation was in effect between genetically different populations.

However, it is assumed that these differences are not artifacts but the consequences of differences in fitness between alleles. Then another analytical approach is required.

In this case, a sample of 500 fish (species: Cheilodactylus macropterus) at one station yielded 10 year classes that showed considerable (sometimes statistically significant) differences in allele frequency that were by analysis of variance shown to be large enough to account for all the station-to-station variation observed in this species.

Similarly, the trevally (Caranyx georgianus) taken in this survey showed the same effect. Plotting allele frequency against estimated station water temperature yields a negative significant regression for both species indicating that it is not a chance, mosaic effect but a genuine selective cline.

Similar effects have been noted in the New Zealand snapper (Chrysophrys acuratus) by Smith (1979) and Smith, Francis and Paul (1978).

It is evident then that allele frequency data requires sorting into identifiably neutral and selective categories before they can be used in assessing a species range for stock subunits.

Four aspects of this sorting process are presented.

1. Understanding the role of the material in question may resolve the problem. For example, it has been shown by Pratschner (1977), that transferring alleles in the coho salmon (Oncorhynchus kisutch) confer different resistance to bacterial disease.

2. Alleles can undergo heavy selection without disturbing the Hardy-Weinberg equilibrium (Leigh-Brown, 1977; Koehn and Williams, 1977).

3. A direct test of the selective status of alleles may be made on the basis of deviations from the expected frequency of neutral alleles derived from the model of Wehrhahn and Guliza, 1979. Many fish and other animals show allele frequencies that deviate markedly from the predicted neutral model (Wehrhahn, Gauldie, Smith and Wu, in preparation).

4. There is some evidence to show that iron in the otolith is correlated to temperature by a mechanism that is independent of species (Gauldie, Graynoth and Illingworth, 1979). Consequently, it may be possible to scan otoliths by x-ray flourescence spectrophotometry and so generate temperature-age profiles for individual fishes. In this way samples can be subdivided into equivalent ecological types and their allele frequency controls so tested directly.

Finally, it should be noted that allele frequencies that are under selective controls are effectively functions of the catalytic properties of the enzyme. That is to say, differences in allele frequency represent differences in some free energy related function. So they are essentially

measurements of potential energy. Differences based on measures of potential energy cannot be used to describe the history of a system. Consequently, genetic distance or identity measurements based on allele frequencies that are selectively controlled cannot be meaningfully used to assign taxonomic status nor time of divergence between class, genus, species or race.

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STOCK STRUCTURE OF NORTH PACIFIC ALBACORE INDICATED BY TAGGING STUDIES, VARIATIONS IN SIZE COMPOSITION, AND DIFFERENCES IN GROWTH RATES

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The National Marine Fisheries Service (NMFS) and the American Fishermen's Research Foundation (AFRF) began conducting a cooperative North Pacific albacore tagging program in 1971. The purposes of the joint NMFS-AFRF albacore tagging study are to (1) examine the migration patterns and stock structure of North Pacific albacore and (2) obtain information for use in population studies. Nearly 15,000 fish have been tagged and released since the start of the joint NMFS-ARFR albacore tagging study. Most of the tagging has taken place in waters offshore of 130°W and south of 37°N, and somewhat lesser amounts in waters offshore of 130°W between 32°-41°N and inshore waters north of 38°N.

Results from the tagging studies suggest that there are at least two sub-stocks of fish that comprise the North Pacific population of albacore and that these sub-stocks have different migratory patterns. A northern sub-stock of fish makes trans-Pacific migrations between the eastern and western North Pacific resulting in an exchange of fish between the northern area (north of about 40°N) of the U.S. fishery and the Japanese livebait fishery, and the longline fishery west of 180°. A southern group of fish have a different migration scheme from the northern group of fish and appear to enter the U.S. fishery south of about 40°N and the longline fishery east of 180°. Only a very small proportion of the southern group of fish appear to migrate between the eastern and western Pacific and enter the Japanese pole-and-line fishery. Also, during a given season there is very little exchange of fish in the U.S. fishery between the northern and southern sub-stocks.

Geographic differences in size composition of albacore taken in the U.S. fishery, and geographic differences in calculated growth rates for tagged fish support the hypothesis that the North Pacific albacore population consists of at least two sub-stocks.

X-RAY SPECTROSCOPY AS A MEANS OF ENCODING ENVIRONMENTAL TAGS

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The premise that niche and habitat variation within the range of a species can lead to detectable variation in the chemical composition of tuna-like species was set forth. The results of previous studies carried out on salmonids, wildfowl and insects were reviewed. In these studies individuals of a species taken from different geographic regions were found to have recognizable differences. On the basis of such differences, organisms were assigned to their area of origin with little error. The elemental composition of the organisms was characterised by x-ray flourescence spectroscopy, a non-destructive form of elemental analysis. The data on each individual organism, in the form of a 1024 word array, is available directly in computer-compatible format. The various forms of pattern analyses carried out on the raw data were described as were discrimination techniques used to classify x-ray spectra with a high degree of repeatability and accuracy.

The analytical and statistical methods used in these studies were illustrated in a videotape presentation. Advantages over more conventional methods of studying population structure include automation, high repeatability, and ease of data handling and processing. Disadvantages are associated with the initial cost of the equipment and the need for suitably trained personnel. Considering the costs involved in studying migratory species with conventional methods, the methods described offer the potential of collecting a much larger, more precise, and more varied data set at a fraction of the cost of more traditional methods.

Methods of collecting data required in tuna management programs were discussed. In general, assuming that analagous differences exist in tuna-like species, the hard parts of organisms may reveal a great deal of information on the vagility, migration routes, the presence of significant sub-division of the resources into overlapping or non-overlapping groups and rates of admixture. Specific applications in existing tuna management programs were discussed as was a pilot study now underway on yellowfin tuna in the eastern Pacific.

SUMMARY - - STOCK IDENTIFICATION TECHNIQUES

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In Session I our task was to address the topic of stock identification techniques suitable for highly migratory species. Specifically, we were charged with addressing the following questions: What identification techniques are applicable to tuna stocks? Are current techniques precise enough for tuna management needs? What kinds of stock identification research are needed?

We have heard a collection of papers which deal with various aspects of these questions. Witold Klawe discussed general attributes of the tuna and billfish epi-pelagic resource and its problems. Emphasis was placed upon the species, that they are migratory, and that they are found throughout the tropical and temperate waters of the world oceans. This discussion is an appropriate starting point for our session, not only because it is important to develop an overview of the resource so that the individual species are kept in perspective, but also because the various species designated form important subdivisions of the resource. Each species differs and contributes to the fishery in some unique way.

Resource managers distinguish between temporal or geographic groupings of a species because these components either are different or are thought to differ in some manner and it becomes useful to recognize these differences. When we are faced with providing a rigid definition of the term "stock", just when we are faced with the task of defining a species, we are pressed to provide a definition that is universally acceptable. The widespread use of the term stock implies that there is a need to subdivide the resource beyond the species category. In many respects, the stock problem is an extension of the species problem. The species problem comes about as a result of our imposing definitive categories upon subjects that vary in the degree of genetic and phenotypic homogeneity. The stock problem arises in part as one result of attempting to give precise definitions to "sub-species variation." Most biologists would agree that the species concept has some evolutionary meaning in that there must be some point in evolutionary time when the individuals within one group of organisms diverge from some other group of organisms to the extent that they can no longer converge. While the species concept breaks down for organisms that reproduce asexually, the biological species concept has meaning with species like tuna. So let us assume that for tuna we can define species in terms of the degree of genetic isolation. If two or more groups of organisms do not interbreed, or if they do interbreed under natural conditions and the offspring are not fertile, we can presume that an adequate amount of divergence has taken place so the groups are evolutionally distinct. So much for resolving the species problem in tuna. How do we resolve the stock problem? By definition, if the groups do

intermingle and do not interbreed to the smallest degree, they are not "good" species. One extreme of the continum we have is the situation where there is no exchange of genetic material between groups, to the situation where there is widespread intermingling within an interbreeding group of organisms. We expect no two individuals to be similar. We also expect to find various kinds of polymorphisms--sexual, dimorphism should be the form familiar to most of us; physiological, morphological, ethological, and ecological polymorphisms are also likely to exist. If a group of organisms or species is spread out over a large range relative to its mobility, so that there is a low probability that individuals on the extremes of the range mate, then we can expect that groups of organisms at the extremes will differ. This is referred to as isolation by distance. Partial barriers to mixing, natural selection, varying degrees of inbreeding, assortative mating and other aspects of the breeding structure of the groups over the range may also vary resulting in differences within species. Some possibilities are illustrated in Figure 1.

In the opening remarks, our chairman, Gary Sakagawa, presented two generic definitions of a unit stock. One definition stresses the genetic aspect; that is a population whose members are genetically alike and self-sustaining. This would imply that one can find groups of organisms that are genetically alike and self-sustaining and that we should use some genetic technique for identifying stocks. This definition suggests that stocks may also correspond to the geneticists concept of a panmictic population. By definition we must assume that stocks or populations are only partially isolated, or if isolated are capable of interbreeding. In this context the important question becomes how distinct organisms from two different areas or from two different time frames have to be before the resource manager accepts and begins to account for these differences in his management strategies? Referring back to Figure 1, the implication is that the manager is looking for the case in which the species is fragmented into a number of isolated groups with little or no intermingling, the last case illustrated. Does this mean that the resource manager need not concern himself with clinical differences or the other kinds of genetic variability referred to in the above discussion?

Assuming that it is important for the manager to be able to identify groupings of organisms within a species that are either partially or totally isolated, we can ask if our methods of detecting this variation are adequate. In the past, blood typing and electrophoretic studies have been carried out in order to define stocks. Robert Gauldie has given his views on the advantages and disadvantages of discriminating appropriate stocks using electrophoretic Techniques. He has touched on two important points. First, many biological and statistical assumptions have been made in the past for electrophoretic techniques using these methods to establish the existence of stocks are not always, if ever, appropriate. Statistical deviations from the theoretical Hardy-Weinberg distribution do not in themselves demonstrate the existence of isolated groups. Most workers assume that no-selection has occurred, that individuals mate at random, and that populations are infinitely large. Gauldie has presented evidence that selection can occur at loci previously believed to be unaffected. Second, given that an investigator has identified a number of polymorphic enzyme systems, one can calculate the genetic distance between samples. We have heard one reason why this method may not be meaningful. The second is that at least for yellowfin and skipjack tuna, there does not seem to be a great deal of enzyme polymorphism that could be used, even if used correctly.

It would appear that even if we did know what level of heterogeneity we were willing to accept as defining "good genetic stocks", present methods leave a great deal to be desired. Besides the fact that the manner in which the Hardy-Weinberg hypothesis, as a null hypothesis is used for the testing for the presence of more than one stock is inadequate, it is not practical in practice to process large enough samples to demonstrate significant differences. Past sampling schemes used in studies of yellowfin and skipjack are not able to distinguish between examples in Figure 1. In tuna, few samples are both polymorphic and the frequency of alleles high enough so that sampling is practical. Many more genetic markers with continuous distributions that assess different loci would be more useful. It may well be that given recent advances in the field of immunology, immunogenetic techniques may be promising. Other techniques from the field of molecular biology also bear consideration.

Gary Sakagawa also suggested a second generic definition of a unit stock, one without reference to genetic homogeneity. A stock may be defined as a collection of organisms with similar population attributes that are fished in one area with the same gear. This definition suggests a practical approach to defining meaningful heterogeneity. Just as it is useful to have a definition of species that refers to sets of organisms that are similar (the typological species concept), it is useful to have a concept of stocks that does not necessarily assume a level of genetic homogeneity.

The relevent questions becomes: are there a collection of animals contained within some area or time stratum that require a unique set of management considerations? In the context of this meeting we may wish to determine if there is some unique collection of organisms within a country's 200-mile zone. A collection that remains there throughout its life history, or returns at the end of its wandering. In this context, an adequate stock assessment method is one with which we can detemine how far individuals range, determine migration routes, rates of intermingling between other groups, determine patterns of similarity within groups, and so on.

William Bayliff discussed two other definition of stocks in his quasi-defense of the use of tagging methods for identifying stocks. The terms sub-population and population are defined. Again, there is reference to the concept of a genetic entity, the panmictic population, and the concept of a collection of similar organisms. It seems obvious that the real advantage gained from tagging studies is not in the delineation of genetic heterogeneity.

While we can infer something about the probability rates of mixing between groups, we must determine from some other method just how much genetic exchange has taken place. Not only must individuals intermingle, they must interbreed. As Bayliff has stated, tagging studies tell one a great deal about the migratory behavior of individuals and can assist with the identification of groups. The problem with tagging studies is that with tuna and billfish, they are costly, seldom succeed in marking a significant proportion of the individuals at large, and a great many of the tags are returned soon after release.

Vladimir Walters has discussed the use of parasites as natural tags. Observed variation in the presence or absence of parasites with relevant life

histories has been the basis for claims by a number of workers that parasite mixes and abundance may be useful markers for stock variation in fishes. While examples of published studies where success has been achieved are few, the methodology holds much promise. The main advantage is that the organisms contain a form of natural tag. The disadvantage is that the tags are biological tags and are subject to loss, to their own peculiar life histories, and to population fluctuations and other demographic processes. In the past, sampling problems have been underestimated. Also, seldom considered is the possibility that the distribution of a parasite may be influenced by environmental factors that do not affect the host. This could lead to faulty inferences about the number of stocks, especially of wide ranging species like tuna and billfishes.

I discussed another form of environmental tag, one that could reflect habitat, ethological, and biological variation. If the habitats of groups differ, if the organisms behave differently in the same habitat, or if the organisms exploit different ecological resources in the same habitat, one can expect to find related chemical differences in the organisms. Whether we can detect these differences is another question. Recent advances in micro-elemental analysis offer the potential of characterizing variation which in turn could be used to classify and identify individuals and groups of similar individuals. Past studies were summarized as were the advantages and disadvantages of the methodology. The methodology holds much promise for the method identifies sets of similar organisms. Each individual is expected to carry along with it a history of its travels and activities.

Many other techniques have been used in past studies of stock identification. Variability in growth rates, fecundity, age and time of spawning, morphology and meristics have and can be used to assess the degree of homogeneity of the resources managers deal with. Recently, radioactive waste contamination has been detected and used to study tuna migration. It would seem that this latter method, as well as others mentioned, can be employed in concert to no small advantage. Michael Laurs has presented the results of an interesting study in which a number of traditional methods have been used to determine variation in the pattern of migration in albacore. The results suggest that sets of organisms exist within one species of albacore in the North Pacific, sets that behave differently. The story is not complete, but the evidence with albacore, as with yellowfin and skipjack tuna, is that while each species as a whole moves great distances within the ocean sub-units, call them populations, sub-populations, or sub-stocks, move about differently.

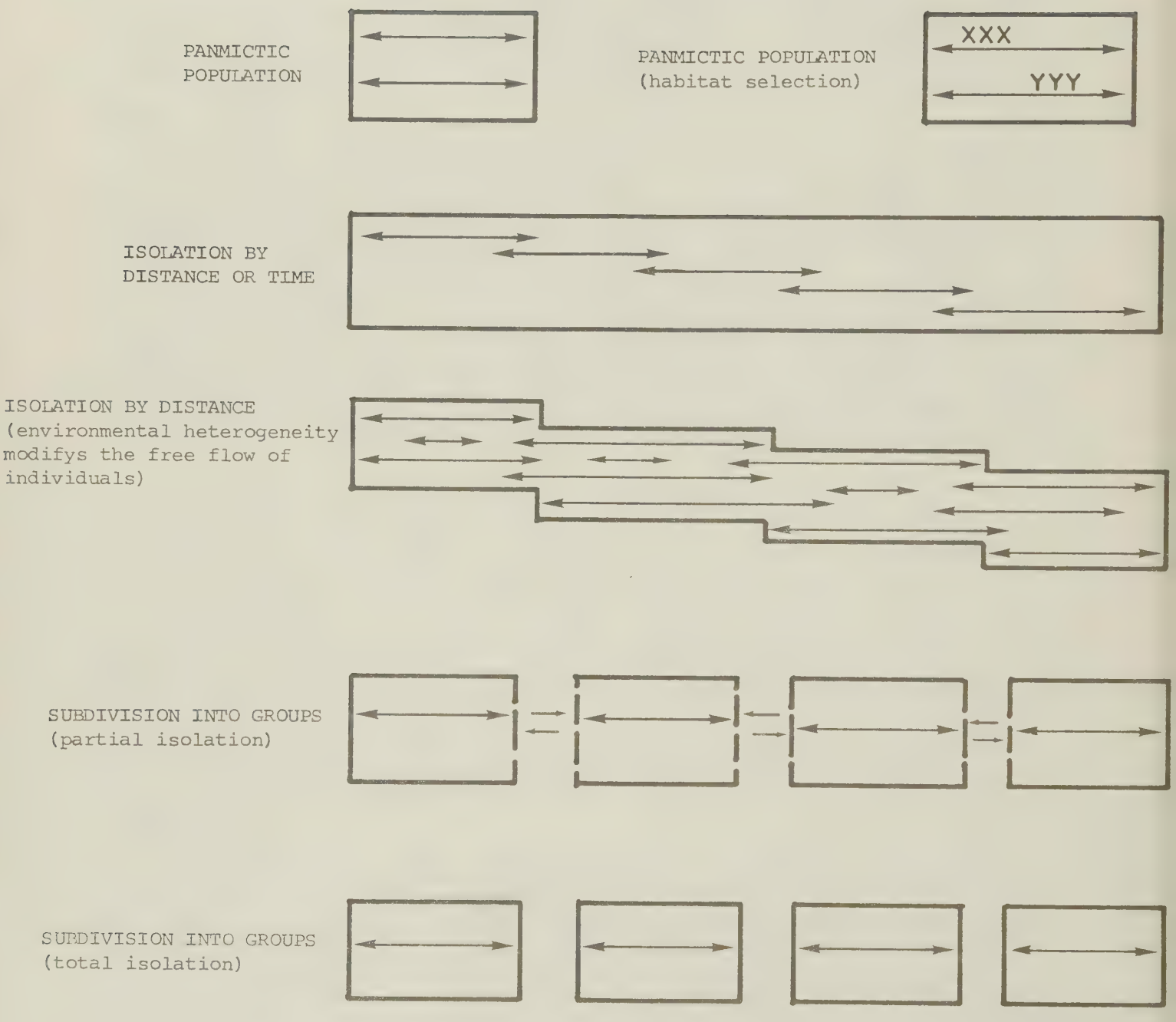
Shall we call these units different species, sub-species, populations or stocks? Shall we arrange each separately; that is, will one set of regulations suffice for all units? These are questions that accompany these findings. Do we wait for definite genetic studies before developing appropriate management schemes? The presence of a significant amount of heterogeneity within a species and between geographic areas makes life more difficult for the resource manager. The deviation of statistics to determine sustained yield, and the usual assumptions may not be appropriate. Estimates of sustained yield in many cases may be lower than they should be, quotas could be raised, and so on. More important, the possibility that a mis-managed resource can result in long term, and permanent, changes is real. There are both long term and short term consequences of neglecting stock

variation in renewable resources. The short term consequence is that we may not be taking as many fish as we could if our tactics were in concert with the existing pattern of heterogeneity. The long term consequence is an even greater reduction in yield, a reduction that may not be easily rectified and for all practical purposes, irreversible.

Reconsider the questions we were asked to address in the beginning. Obviously, present genetic techniques for defining the level of heterogeneity in species that warrant some management consideration are certainly inadequate. While we would like our management units to be "good sub-species" or whatever; the question may not be relevant in the long term. We need not, or should not, wait until all of the details are available. The other techniques we now have, whether traditional or modern, can yield either singly or collectively a great deal of information about heterogeneity. What is more restraining than the availability of technique is the lack of conviction on the part of many investigators and administrators that the information is really needed or even relevant. This in turn suggests that of all methods available, heuristic modeling studies may be the method most likely to have an impact on the unit stock concept in fisheries. We need some form of demonstration of the importance of accounting for heterogeneity in management schemes, the advantage and disadvantage of doing so. It should not be difficult to demonstrate that management considerations must be geared to account for, to harvest, and to protect the pattern of phenotypic and ecotypic variation. I can only conclude that the stock problem in tuna and billfish remains one not because of fundamental deficiencies in methodology but rather deficiencies related to conviction and support.

Figure 1

POSSIBLE BREEDING STRUCTURE OF A RESOURCE
-some alternatives-



STATUS and POTENTIAL YIELD from TUNA STOCKS

Robin Allen, Convenor

STATISTICS ON WORLD TUNA STOCKS AND FISHERIES WITH U.S. PARTICIPATION

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This presentation examines the harvest of world tuna by species, ocean, and geographic area. Tunas inhabiting certain geographic areas and generally considered to be stocks are discussed using catch trends, maximum yields, estimates of maximum sustainable average yield, and current international regulations. United States catch levels are compared to world catch by species and ocean. The purpose of this presentation is to place in perspective the major tuna species which will be discussed at this Conference, and provide an outline of the knowledge available regarding these species. In addition, the degree of U.S. involvement in tuna fisheries can be evaluated by comparing catch levels with the total world catches.

The 1977 marine fisheries catch for the world was 63 million metric tons (MT). Catch of tuna and tuna-like species accounted for 4% of that, or approximately 2.3 million MT. Two species, skipjack tuna (Katsuwonus pelamis) and yellowfin tuna (Thunnus albacares) make up over 50% of that catch, or slightly more than one million metric tons. If albacore (Thunnus alalunga), bigeye tuna (Thunnus thynnus), and southern bluefin tuna (Thunnus maccoyii) are included, almost 3/4 of the world's tuna catch is represented.

The major species catch levels are presented based on the 1975 tuna catch. Skipjack tuna and yellowfin tuna make up more than fifty per cent of the catch in each ocean (Figure 1). The Pacific Ocean has the highest catch level with 69% of the world tuna catch. The least diversity also occurs here with 73% of the catch composed of skipjack and yellowfin tunas. Six major species account for 96% of the Pacific tuna catch. The Atlantic Ocean yields 20% of the world tuna catch. Skipjack and yellowfin tunas make up 56% of the catch with the six major species accounting for 99%. The Indian Ocean yields 11% of the world tuna catch. Skipjack and yellowfin tuna make up 51% of the catch. Most of the southern bluefin tuna are caught here and make up 14% of the catch. No bluefin tuna are caught in the Indian Ocean and the remaining 5 major species comprise 90% of the catch.

Catch trends of combined tuna and tuna-like species are different in each ocean. The Pacific Ocean shows an increase of almost 50% in catch from 1970, at about one million metric tons, to one and one-half million metric tons in 1976. The Atlantic catch has remained relatively stable over the same 5 year period at about 400 thousand metric tons. The Indian Ocean catch has increased only slightly over the same time span from about 200 thousand metric tons to a little over 250 thousand metric tons.

Schematics of distribution and fishing areas in the Atlantic and Pacific

were presented and discussed for each of the six major species (Figures 2 and 3). Distribution is shown in the open cross hatching and is intended to be very general in nature. General fishing areas are depicted by finer cross hatching which is not intended to represent catch or effort density.

Some statistics were presented for the major species in the Atlantic and Pacific (Table 1). The statistics as presented are:

GEOGRAPHIC AREA - Indicates a segment of the resource or separate areas where fisheries have developed;

PER CENT CATCH BY OCEAN - Shows the percentage each ocean contributes to the total catch of an individual species;

CATCH TREND - Indicates recent changes in the fishery particularly in the last 5 years;

MAXIMUM ANNUAL CATCH (YEAR) - Shows maximum catch in thousands of metric tons followed by the year in which that catch occurred;

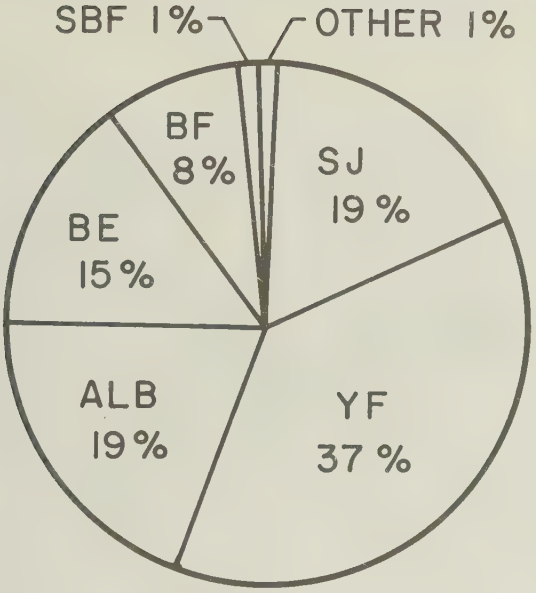
MSAY - This represents the maximum sustainable average annual yield in thousands of metric tons;

INTERNATIONAL REGULATIONS - Shows where management attempts are being made on these highly migratory species.

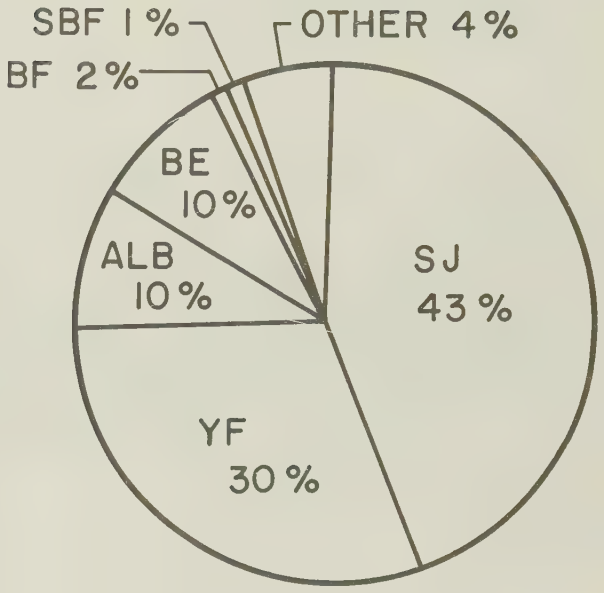
The U.S. catch of tuna and tuna-like species amounts to about 17% of the world catch based on 1975 figures. The primary Pacific Ocean species captured by the U.S. fleet are yellowfin tuna, skipjack tuna, and albacore. The primary Atlantic-caught species are yellowfin, skipjack, and bluefin tunas.

Figure 1

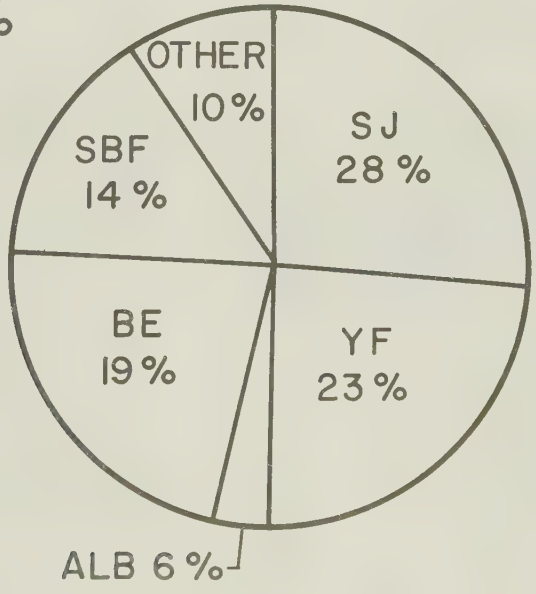
1975 TUNA CATCH COMPOSITION BY OCEAN



ATLANTIC 20%
(320 x 10^3 MT)



PACIFIC 69%
(1,084 x 10^3 MT)



INDIAN 11%
(169 x 10^3 MT)

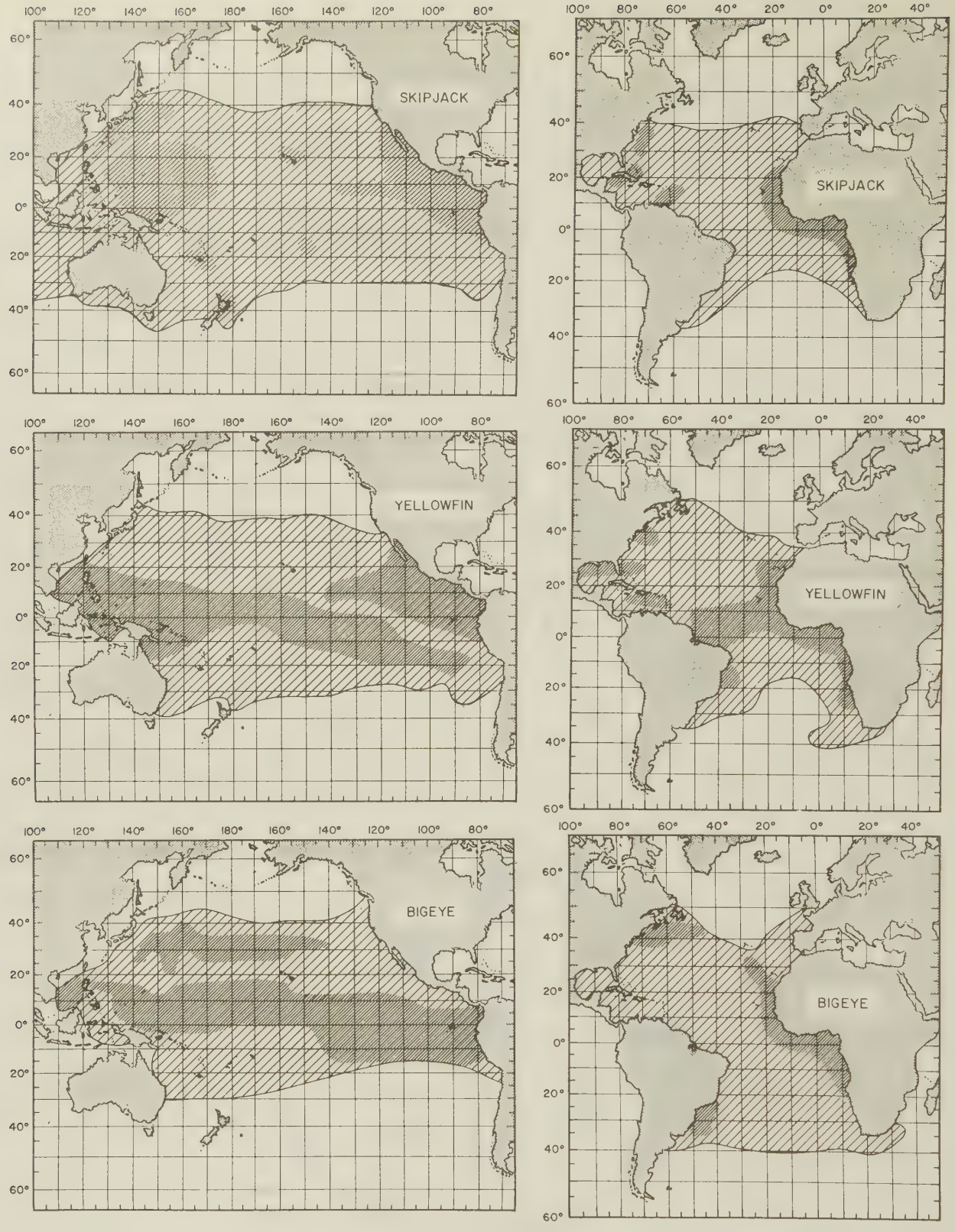


Figure 2. General distribution and general fishing areas for the six major commercial species in the Pacific and Atlantic Oceans.

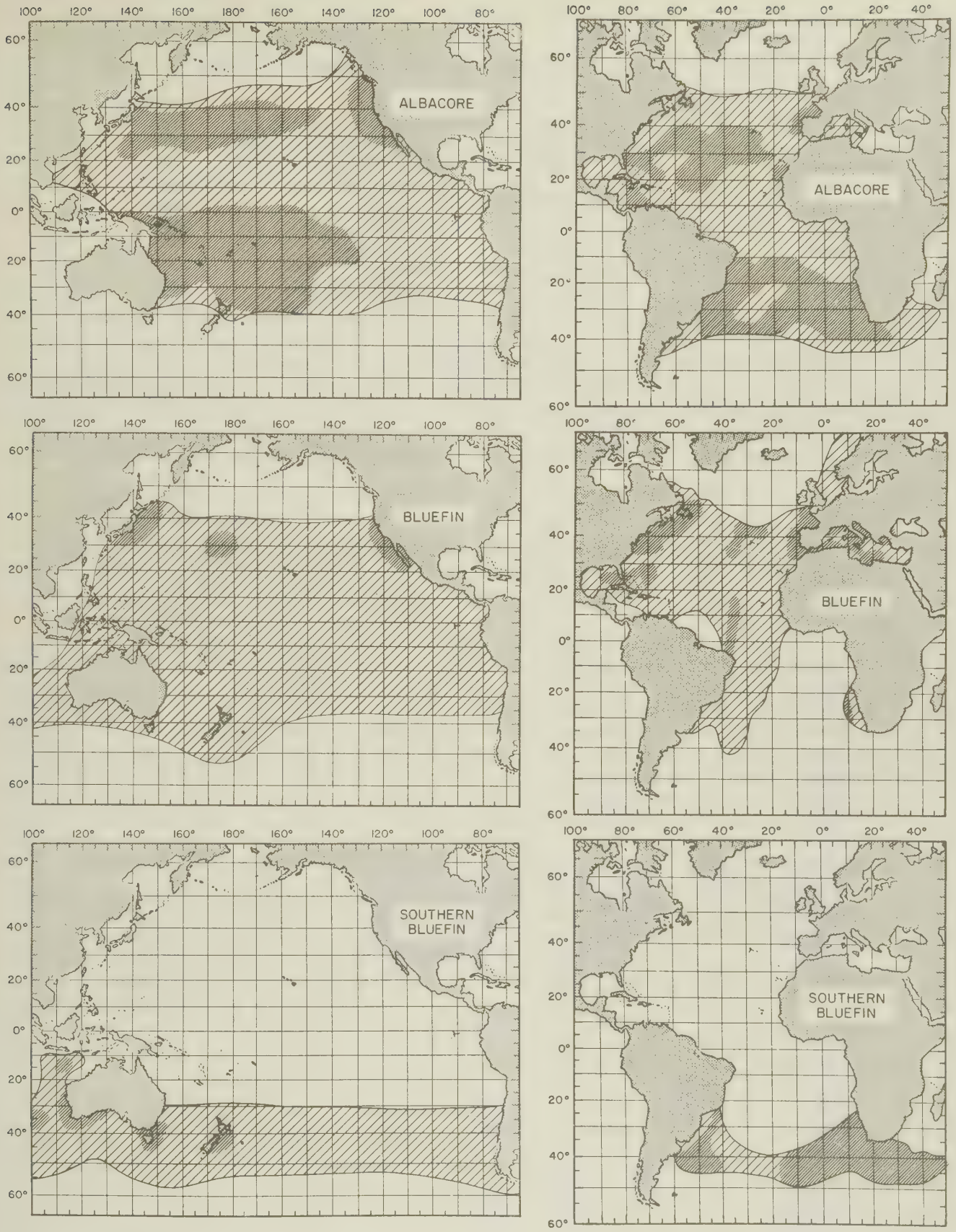


Figure 2. Continued.

Table 1. Some statistics for major commercial tuna species by geographical area

Geographic Area	Percent catch by Ocean 1975	Catch Trend	Max. Annual catch (year) $X10^3$ mt	Max. US Annual catch (year) $X10^3$ mt	MSAY[1] $X10^3$ mt	International Regulations
ATLANTIC			SPECIES - SKIPJACK TUNA			
Total	11%	Increasing	122(1977)	21(1973)	None	None
East		Increasing	118(1977)	21(1973)	118	None
West		Steady	3(1976)	0.5(1976)	None	None
PACIFIC						
Total	81%	Increasing	535(1976)	120(1976)	None	None
East		Steady	141(1976)	116(1976)	None	None
West		Increasing	407(1974)	<10(1977)	None	None
ATLANTIC			SPECIES - YELLOWFIN TUNA			
Total	24%	Increasing	130(1977)	19(1969)	108-162	3.2 kg.min. size ICCAT July 1973
East		Increasing	112(1977)	19(1969)	90-100	
West		Increasing	11(1977)	1(1977)	14-18	
PACIFIC						
Total	65%	Increasing	324(1976)	173(1973)	---	None
East		Increasing	209(1976)	173(1973)	175	IATTC quota (not '79)
West		Increasing	115(1976)	< 2(1977)	---	None
ATLANTIC			SPECIES - BIGEYE TUNA			
Total	26%	Increasing	52(1974-75)	1(1974)	49-55	3.2 kg.min. size ICCAT proposed
North		Increasing	40(1974)	---	34-39	
South		Increasing	22(1971)	1(1974)	16-18	
PACIFIC						
Total	59%	Increasing	108(1976)	3(1975)	90	None
North		Increasing	69(1976)	3(1975)	None	None
South		Increasing	41(1975)	---	None	None
ATLANTIC			SPECIES - ALBACORE			
Total	33%	Decline	88(1965)	0.013(1974)	---	None
North		Decline	58(1965)	0.013(1974)	49	None
South		Steady	41(1972)	---	28-32	None
PACIFIC						
Total	61%	Steady	150(1977)	21(1974)	---	None
North		Steady	122(1976)	21(1974)	100-120	None
South		Decline	42(1966)	---	33-35	None
ATLANTIC			SPECIES - NORTHERN BLUEFIN TUNA			
Total	60%	---	26(1976)	2.5(1970)	None	6.4 kg.min. size ICCAT Aug. 1975
East		Steady	10(1975)	---	None	
West		Steady	6(1977)	2.5(1970)	None	
Mediterranean		Decline	16(1976)	---	None	
PACIFIC						
Total	40%	Decline	25(1971)	9(1973)	None	None
East		Decline	15(1971)	9(1973)	None	
West		Fluctuating	14(1972)	----	None	
SOUTHERN HEMISPHERE			SPECIES - SOUTHERN BLUEFIN TUNA			
Atlantic	5%					7 year min. age. Japan self-imposed
Pacific	28%	Decline	65(1961)	None	None	
Indian	67%					

[1] Values not to be cited without contacting author for source document.

UNDERUTILIZED STOCKS OF TUNAS AND THEIR POTENTIAL

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In the world's oceans there are about 50 tuna and tuna-like species. Seventy-five percent of the world's catch of tunas is made up of skipjack, albacore, yellowfin, bigeye, north bluefin and southern bluefin; 20 percent are the tuna-like species, bonito, mackerels and black skipjack and five percent are billfishes. This discussion will include only the major market species.

The Atlantic tuna catches range from about 360,000 to 400,000 metric tons each year, the Indian Ocean 180,000 to 200,000 metric tons and the Pacific Ocean about 1.0 million to 1.2 million metric tons. The total world catch today is about 1.8 million tons.

To determine if there are any underutilized stocks of tunas, one need only to look at the methods of tuna fishing and the areas being fished around the world. Only longline gear is harvesting the large subsurface schools. Surface schools are captured during daylight hours. Other catching methods may yield production from the mid-water levels or during the evening hours. There are areas in the three major oceans where small tunas are not fished, but oceanic conditions suggest that tunas may be available. Through expansion of current fisheries, special survey work and development of new gear and fishing techniques, these potential tuna resources could be harvested.

Skipjack with its current annual production at about 600,000 metric tons, could be increased to 1.0 to 1.2 million metric tons; yellowfin from 570,000 to 650,000 or 700,000 metric tons; albacore from 250,000 to 300,000 metric tons; bigeye from 200,000 to 250,000 metric tons; and longtail tuna from about 5,000 up to 50,000 metric tons or perhaps 100,000 metric tons. The total annual world production of tunas has a potential of about 2.5 to 2.6 million metric tons.

STATUS OF THE EASTERN PACIFIC YELLOWFIN STOCK

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Early estimates of average maximum yield from the yellowfin stock within the Regulatory area of the IATTC were between 90 and 100 thousand short tons. These estimates were based on a fishery operating in the onshore portion of the range of the stock. As the fleet expanded its area of operation offshore (by more than a factor of 4) catches and indices of abundance increased more rapidly than expected. In 1969 the Commission began a program to experimentally determine the potential yield for the expanded area by progressively increasing the annual harvest from the stock. The results of intentionally attempting to harvest more than the estimated surplus production from the stock would be useful in redefining the population parameters necessary to assess abundance. The catch in the CYRA was increased from about 90 thousand tons to about 200 thousand tons over a period of nearly 10 years, and recently has averaged about 190 thousand tons. During the same period the index of relative apparent abundance has decreased by about one-half. The best estimate based on general production models of the average maximum sustainable yield is about 175,000 short tons, suggesting the possibility of slight overfishing. Examination of the age composition of the catch has demonstrated a marked fluctuation since 1973, the onset of heavy fishing. The catch is normally made up of five age classes with ages 2 and 3 contributing most heavily to the catch. In 1973 and 1974 age-1 fish contributed most heavily to the catch. In 1975, 1976, and 1977 the older age classes, 2-5 years old have made poorer than average contributions to the catch. In 1978 the age-1 fish have made the largest contribution to the catch in the history of the fishery and the 2-5 year olds have continued to contribute poorly to the catch. Although the general production analysis does not show cause for concern, the age-structure data suggest caution in maintaining the high levels of catch.

AN ASSESSMENT OF ATLANTIC BLUEFIN TUNA RESOURCES

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Atlantic bluefin tuna live 20-30 years if not caught and grow up to 320 cm and 700 kg. The distribution is Atlantic wide, 70° north to 45° south (except the Gulf of Guinea), the Mediterranean Sea, and Black Sea. Fish spawn in the Gulf of Mexico in May and the Mediterranean Sea in July. Nursery areas include the southern and central Atlantic U.S. coast, Moroccan coast, Bay of Biscay, and Mediterranean Sea. Adult fish marked in the Bahama Islands in the spring migrated to the Canadian and Norwegian coast by fall of the same year. Those released off Norway have been caught in pre-spawning condition in the Gibralter area while migrating into the Mediterranean the following summer. Those released off the Canadian coast in the fall have been caught in the Gulf of Mexico the following spring. Adults released in the Bahamas migrated as far south as the Argentina coast and as far north as the Arctic Circle off Norway. Juvenile fish released off the U.S. coast have been recaught in the Bay of Biscay and vice versa.

Numerous Atlantic bluefin fisheries, discrete geographically and temporally, are directed at small (juveniles, (3-50 kg) or large fish (100-400 kg)). About 13 countries are presently involved in the fishery using longlines (L), traps (T), handgear (H) including harpoons, handlines and rod and reel, and surface gear (S) including purse seines (PS) and baitboats. Significant fisheries exist in the following areas:

	Mar-May		Jun-Jul		Aug-Oct		Nov-Feb	
	small	large	small	large	small	large	small	large
Mediterranean Sea	PS		PS	PS,T	PS		PS	
Bay of Biscay			S		S			
Norwegian Coast				PS		PS		
Gibraltar area				T		T		
Canary Islands			S		S	S		S,L
Moroccan Coast			S		S			
Gulf of Mexico		L						
North American Coast			PS			T,H,PS	L	
Off Central Brazil		L						L

From 23 to 26 thousand metric tons are reported landed each year. About 15% of the annual nominal landings are caught in the West Atlantic, 50 to 60% in the Mediterranean Sea, and the remainder in the East Atlantic.

During the years previous to the late 1960's the catch of juvenile fish (age 1-5) increased appreciably (Figure 1). Analyses indicate that the yield per recruit dropped 15% in the Western Atlantic and 50-60% in the Eastern Atlantic as a result of that expanded surface fishery for juvenile fish. Over

the period 1960-76 the adult catch has fluctuated annually, however, a slight downward trend is evident.

Annual catches of each nation-gear-area fishery were sized with available length and weight composition samples and aged from a von Bertalanffy function developed from mark-recapture data (Figure 2).

Virtual population estimates of adult stock size (age 6+) were found to be extremely sensitive to the assumed fishery mortality rate (F) during the last year of catch for F's less than 0.5 and very stable for F's of 0.5 and greater (Figure 3).

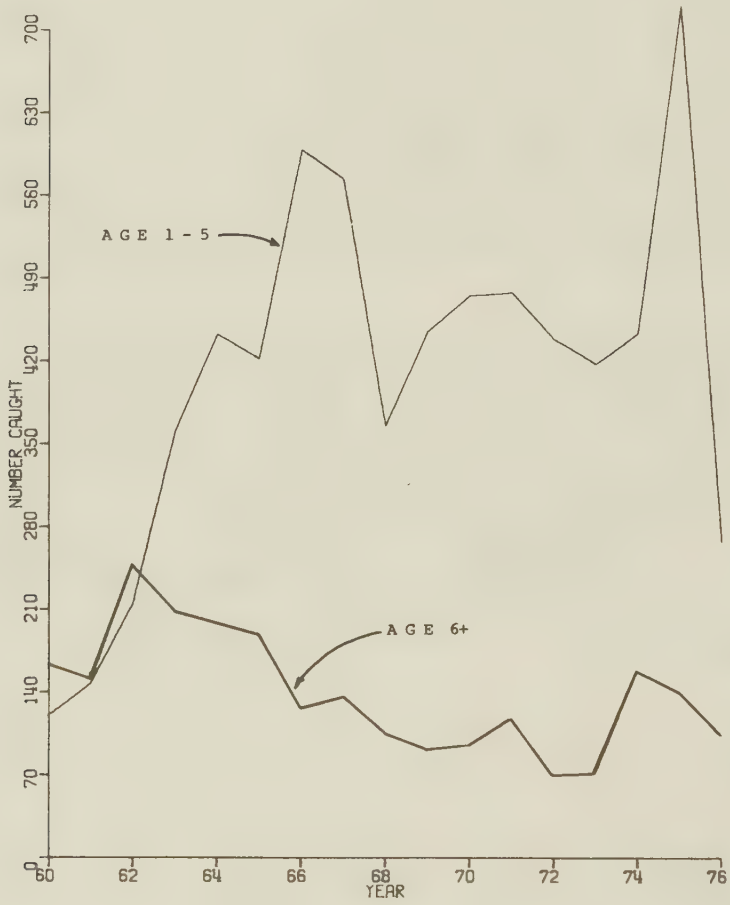

Figure 1

The von Bertalanffy growth model for Atlantic bluefin tuna derived from mark-recapture data.

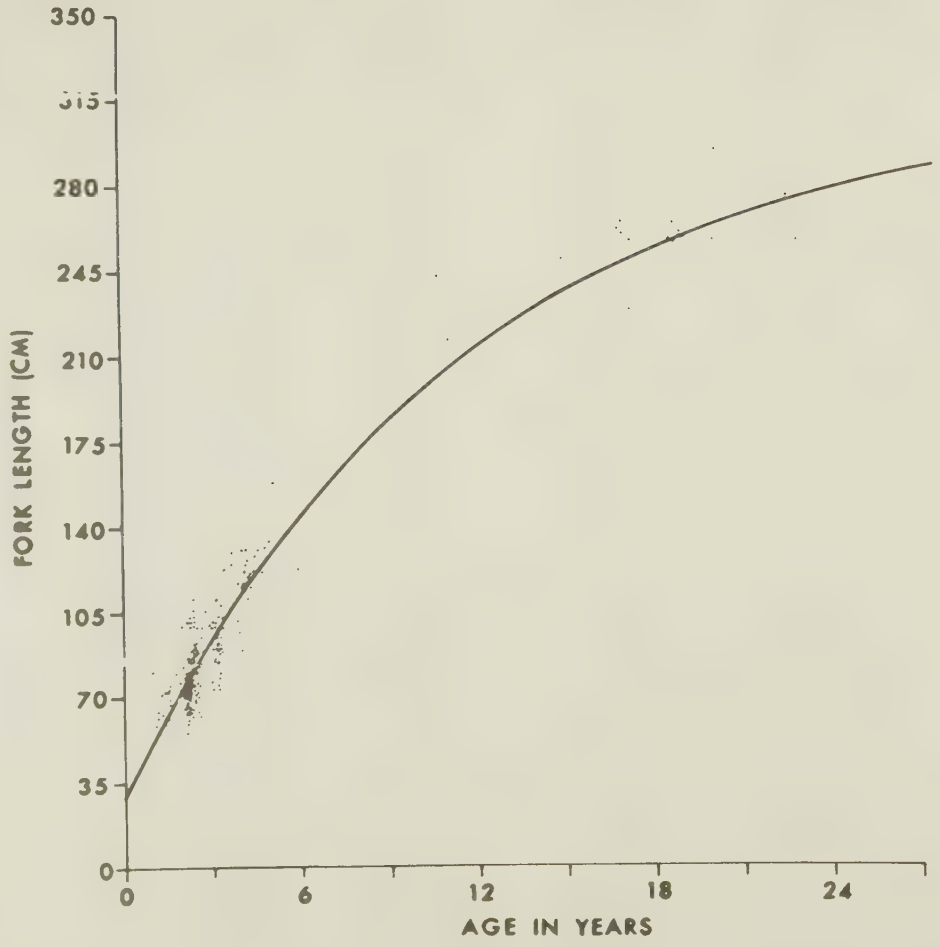

Figure 2

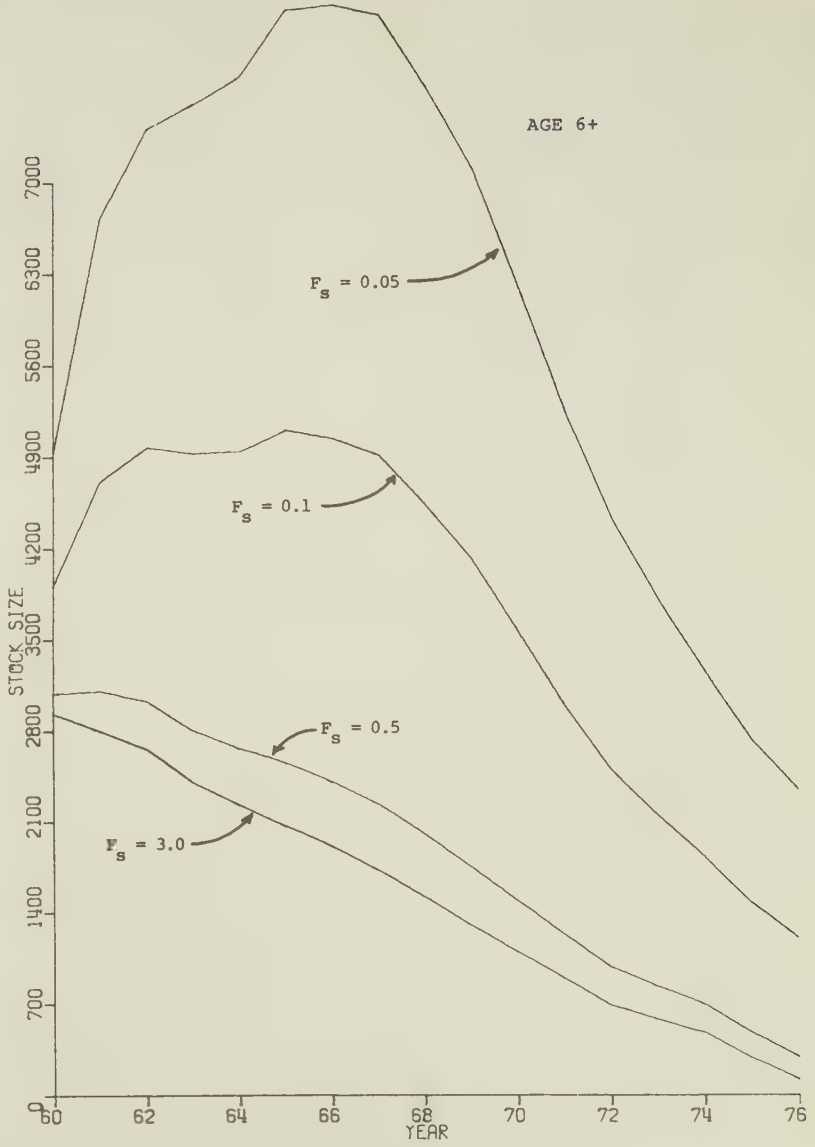

Figure 3

AN ASSESSMENT OF THE STATUS OF STOCKS OF BLUE MARLIN AND WHITE MARLIN IN THE ATLANTIC OCEAN

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INTRODUCTION

The status of stocks of blue marlin and white marlin in the Atlantic Ocean is considered using production model analysis. The analysis is conducted under two stock structure hypotheses and under three hypotheses concerning the number of significant year-classes in the catch. The status of stocks under each hypothesis is measured in terms of the usual management criteria of maximum sustainable yield (MSY) and the associated optimal fishing intensity (f_{opt}). Sensitivity analysis is conducted to measure the variation in management criteria due to the various stock structure and year-class hypotheses employed in the analysis.

HYPOTHESES EMPLOYED

Stock structure of both blue marlin and white marlin in the Atlantic Ocean is unclear because of conflicting evidence from standard data sources such as catch rate distribution, larval distributions, and tagging data. Thus, two stock structure hypotheses were employed for both species: (1) a single Atlantic stock and (2) separate North and South Atlantic stocks.

Similarly, length-frequency data indicates that four, five, or six year-classes may be significant by weight in the blue marlin catch; while three, four, or five year-classes may be significant in the white marlin catch. These three year-class hypotheses were employed for blue marlin and white marlin, respectively.

DATA AND METHODS

Atlantic-wide commercial and recreational landings data were compiled by country for the period 1956-76. Total Atlantic landings were then partitioned into North and South Atlantic landings using the equator as the dividing line.

Japanese longline catch and effort statistics by quarter of the year and by five degree area were used to estimate annual effective fishing intensity for the Japanese fleet. Japanese catch-per-unit of fishing intensity was then used as the index of abundance for both species. Total fishing intensity was estimated by the quotient of total all country catch and this index of abundance. The generalized stock production model was fitted to the index of abundance and a weighted average of total fishing intensity.

RESULTS

Although a large amount of variability in the South Atlantic data limited the interpretation of the catch/effort relationship for the hypothesized South Atlantic stocks of both species, the results generally indicate that blue marlin stocks may have been overfished in recent years while white marlin stocks have been fished at or near the MSY level. Figures 1 and 2 illustrate the observed catch, fishing intensity, and equilibrium curves for blue marlin and white marlin, respectively. Sensitivity analysis indicated that while MSY is only moderately sensitive to the stock structure hypothesis employed, f_{opt} appears to be very sensitive to the hypothesis employed. However, neither of the management criteria were found to be sensitive to the number of year classes assumed to be significant in the catch.

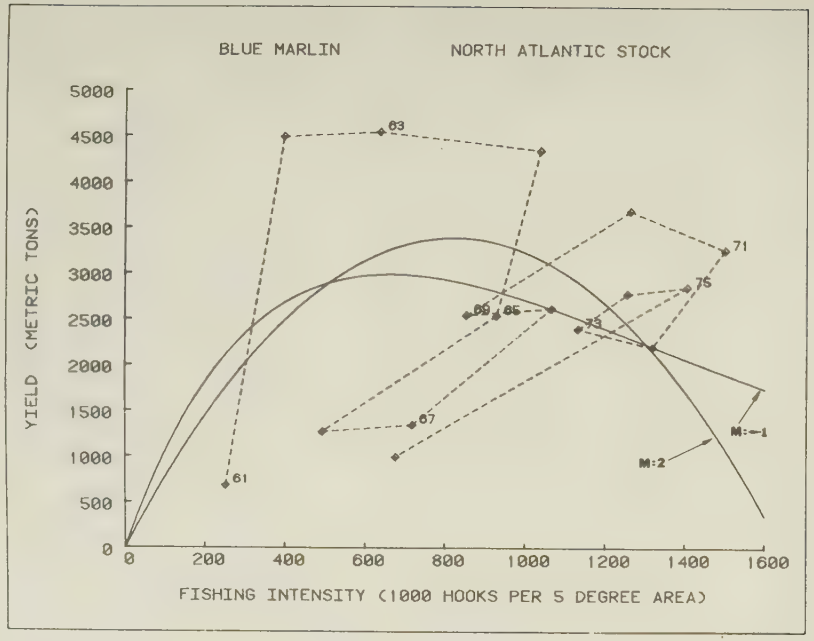
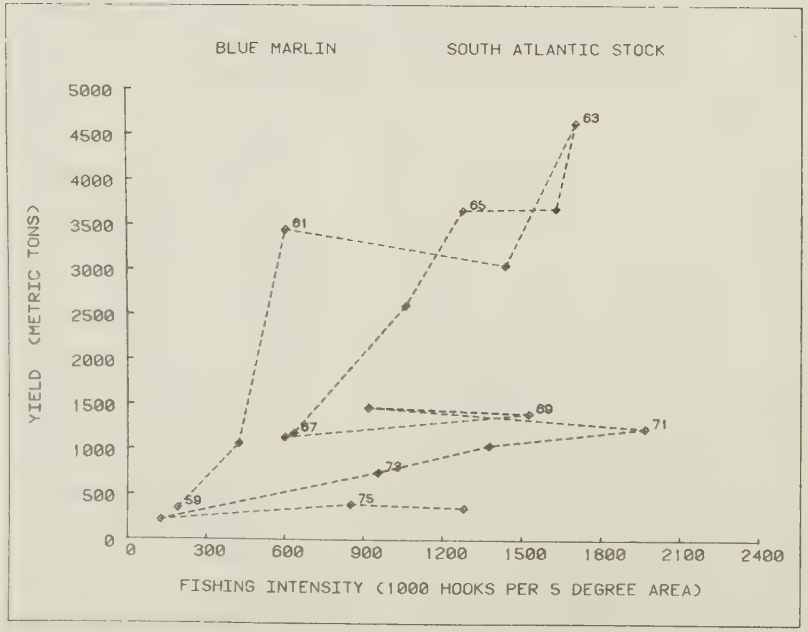
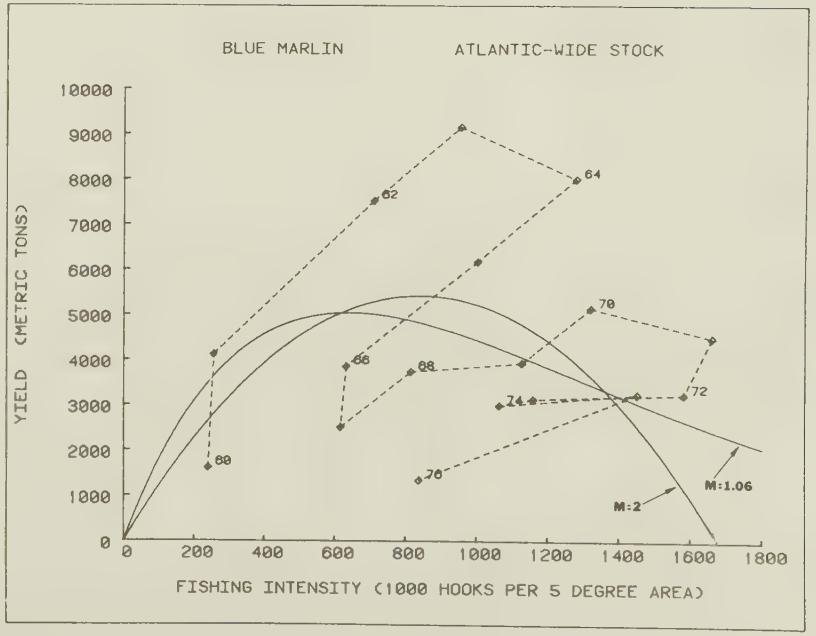


Figure 1. Observed catch, fishing intensity, and equilibrium curves for blue marlin under two stock structure hypotheses. Five year-classes are assumed to be significant by weight in the catch.





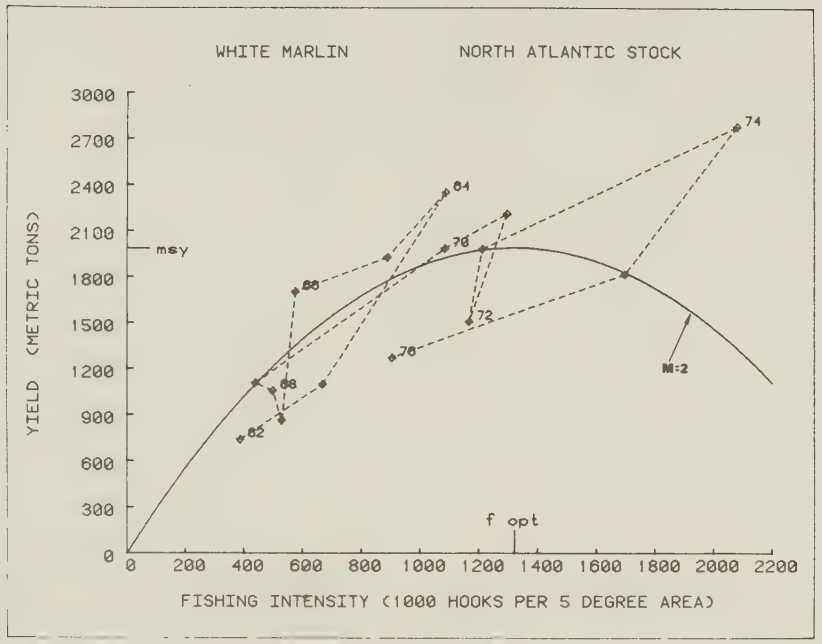
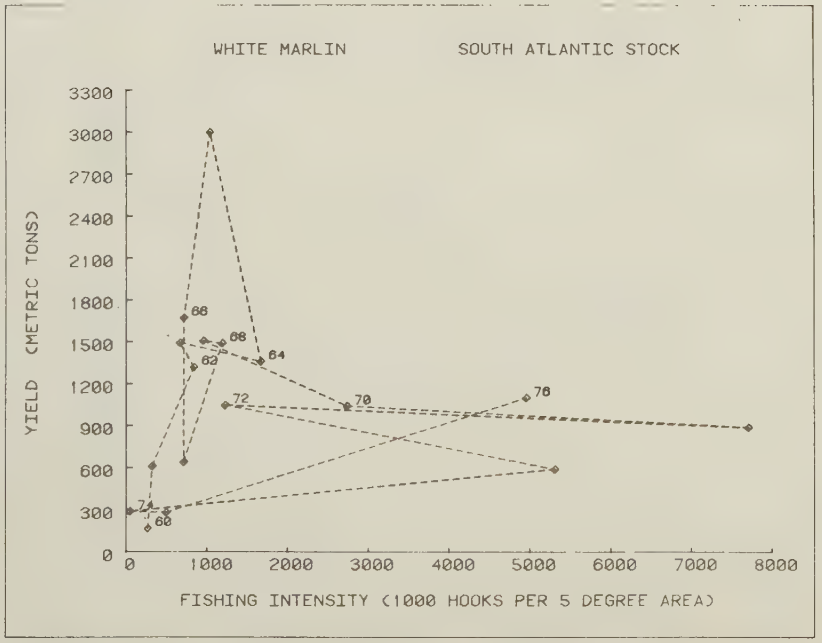
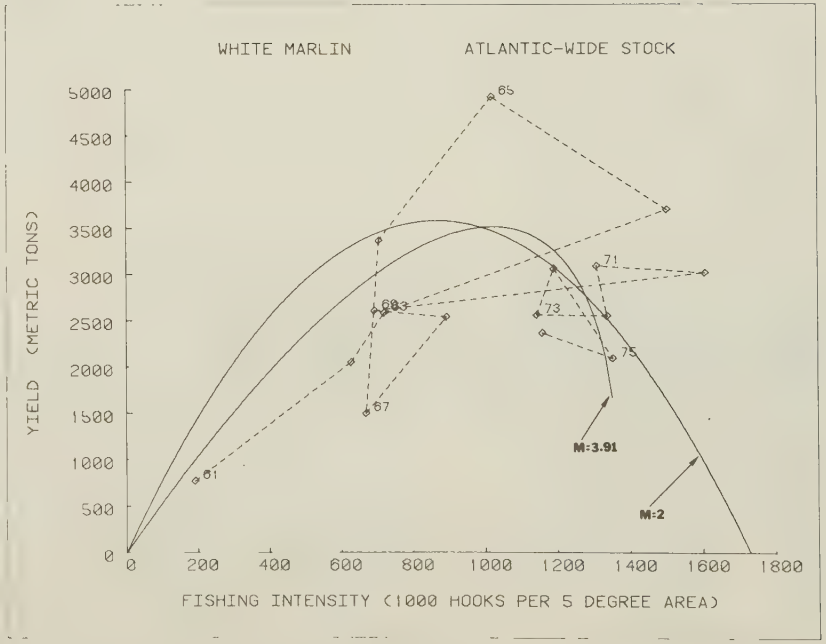


Figure 2. Observed catch, fishing intensity, and equilibrium curves for white marline under two stock structure hypotheses. Four year-classes are assumed to be significant by weight in the catch.





ABUNDANCE ESTMATION OF A NONRANDOMLY DISTRIBUTED FISH POPULATION FROM HARVEST DATA

Jeffrey Laake and Richard Punsley

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The management of a fishery by the unit stock concept can only be realized if there are suitable methods to determine the relative abundance of the stock. The determination of abundance is a central problem to fisheries management or any natural resource management. Marine fisheries managers have many unique problems with abundance estimation because they usually rely on commercial harvest data. The use of harvest data can provide many inherent biases in the analysis because the fishermen are always attempting to maximize their catch for the minimum effort. This amounts to increasing their efficiency or concentrating their efforts in good fishing grounds. The latter approach provides a biased sampling scheme which produces higher catch per unit of effort than would be expected if the fishermen sampled randomly. Also, unless they are able to duplicate their efforts with respect to the density of fish then the catch per unit of effort will not necessarily reflect changes in abundance from year to year.

One of the following three possible situations must exist before an unbiased estimate of relative abundance can be obtained: 1) the distribution of fish is random and fishermen search randonly, 2) the distribution of fish is random and fishermen search nonrandomly. None of these situations occur in most fisheries.

Gulland (1955) recognized the problem of concentration of effort in his work on haddock and plaice. He suggested dividing the whole area into smaller equal sized areas and then assume that the sampling within the small areas was random. Then estimates of catch-per-unit of effort could be calculated for each of the small areas and weighted by area size to get a combined estimate. The essence of this approach is to create areas of homogeneous effort from a larger area which is nonhomogeneous. However, there are two problems with the way Gulland (1955) incorporated this approach: (1) arbitrary stratification may not create homogeneous units unless the areas are relatively quite small and (2) if the areas are very small then there will be many areas in which no effort was expended and no estimate can be made (therefore we must assume they are empty).

An alternative to Gulland's (1955) arbitrary stratification is to stratify based upon some feature of the data. If the data could be stratified such that either the effort was random or uniform within areas or the density was homogeneous within areas then the second and third situations described above could be obtained. Thus an area could be divided into very small areas and then these areas could be put into strata on the basis of the effort (e.g., number of days fishing) or the density (e.g., number observed per unit time or distance) by an objective clustering algorithm or a subjective approach. This approach does not completely solve the problem of areas of no

sampling because these areas would be included with those of little effort or low density.

A natural extension to the approach discussed above has been proposed by Burdick (1979) in reference to estimation of dolphin density in the eastern tropical Pacific. He has suggested fitting a two dimensional surface to the observed density (number per unit distance) and the estimate of relative abundance is the volume under the surface. This approach provides a smoothed version of stratification which is a two dimensional step function. It also avoids defining any boundaries for strata which are quite artificial. This method extrapolates on the basis of the trend in the data for areas where no sampling occurs.

We conducted a simple computer simulation to examine initially some of the stratification methods. A 40 by 40 unit area was defined in which 1000 schools of fish were located. Three distributions of schools were used. Two of the distributions were defined by a bivariate normal with the mean in the center of the area and standard deviations of 6 and 10 in both dimensions. The third distribution was random. A nonrandom search by fishermen was simulated by having their probability of staying in an area dependent on their success in the previous time steps. The output of a simulation was two 40 by 40 matrices with one showing the effort and the other the catch. The following three methods of stratification were examined: (1) arbitrary stratification in square 5 by 5 units, (2) stratification by catch per unit time and (3) stratification by effort. The latter two stratification methods were implemented by subjective examination of the matrices.

Five replications of each of the three distributions of fish were simulated. Estimates were made from the stratification methods and unstratified. The average percent relative bias of the estimates are presented in Table 1. The results illustrate that all of the stratification approaches reduced the bias considerably. Arbitrary stratification underestimates because of the lack of sampling in certain areas. Conclusions about density and effort stratification cannot be made due to the subjectiveness of the stratification and the small sample size of replicates. However, they do reduce the bias and have advantages over the arbitrary method if they are implemented objectively. Further work in the direction of Burdick's (1979) approach and comparing it to an objective stratification based on density or effort should be fruitful.

Literature Cited

Burdick, D.L. 1979. On estimating the number of porpoise schools. Unpubl. manuscript.

Gulland, J.A. 1955. Estimation of growth and mortality in commercial fish population. Fish. Invest., Lond., Ser.2, 18(9):1-46.

Table 1. Average percent relative bias of the estimates from simulation of 5 replications for unstratified and various stratified approaches.

Distribution	Stratification type			
	Unstrat.	5 x 5	Effort	Density
Bivariate normal (σ_i=6,i=1,2)	64.8	-20.4	-16.1	12.3
Bivariate normal (σ_i=10,i=1,2)	60.1	- 8.5	-23.3	6.8
Random	7.6	-27.0	- 3.3	7.6

DOLPHIN DISTRIBUTION AND ENVIRONMENT

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An important ingredient in the assessment of eastern Pacific dolphin populations is their habitat space. There are at least 15 species/stocks of dolphins in the Eastern Tropical Pacific (ETP), 5 of which interact significantly with the yellowfin tuna fishery. Their areal distributions and the types of interspecific interactions correspond broadly with oceanographic regimes which thereby provide information on habitat space. The data analyzed were "observer" records through 1976 and research cruise data up to the present.

The ETP may be divided into 4 regimes of surface water types. These are the Tropical, Equatorial, Transition, and Subtropical water masses. The Tropical Water is the main habitat of the tropical, pelagic dolphins. The identity of these water masses are readily apparent from their temperature and salinity structure.

Plots of dolphin sightings along oceanographic sections reveal a broad grouping of the sightings along the 10^{o}N and the equatorial divergence zones of the Tropical and Equatorial waters respectively.

Spotted and spinner dolphins (Stenella attenuata and S. longirostris) are more broadly distributed about the divergence zones than are the striped and common dolphins (S. coeruleoalba and Delphinus delphis), and therefore are found over a broader range of mixed layer depths and higher surface temperatures than the latter group. However, striped and common dolphins more often occur along the equator, so are frequently found in waters of weak thermocline gradient.

The spotted dolphin primarily occurs in the tropical waters, which greatly expand and contract with season the south of the equator. Eastern spinner dolphins are found generally in waters off Mexico, influenced by the California and Costa Rica currents. There is evidence for separate stocks of both spotted and spinner dolphins in the distinct oceanographic regime south of the Galapagos Islands. Both striped and common dolphins show three axes of distribution and can be extensively distributed along the equator in warm seasons/years.

Seasonal aspects of distribution were investigated during October-November of 1977. Spotted and spinner dolphins were found aggregated along the southern boundary of the Tropical Water along the equator (Equatorial Front) during that season. However, observers reported these species occurring within the cold waters to the south also. The cold water regime of the southern winter apparently induces a more contagious distribution of schools, but not large scale migrations. This supports other evidence of the

distinctiveness of the southern hemisphere stocks.

Dolphin-tuna-bird associations vary with area and season. Tropical Water, locus of the purse-seine tuna fishery, is characterized by large associations of dolphins, tuna, and birds. Equatorial waters have relatively few fish-cephalapod feeding birds to interact with tuna and dolphins. In the Subtropical waters bird flocks may be abundant, but dolphin schools tend to be small and separated from tuna and birds.

SUMMARY -- SESSION ON STATUS AND POTENTIAL YIELD FROM TUNA STOCKS

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The papers in this session covered a wide variety of topics from description of existing fisheries, predictions of yield from untested fisheries, state-of-the-art assessment of specific fisheries, exploration of the impact of the environment on distribution, and on techniques of treating data.

The current catch of tunas is about 1.8 million metric tons and by exploiting areas with similar features to those with existing fisheries it was suggested that the total might be increased to the vicinity of 2.5 million metric tons. The suggestion of exploiting new areas brought up the question of the relationships of stocks in different areas, and thus of the impact of new fisheries on stocks supporting existing fisheries. Furthermore proposed increases in catch required that markets will be available at the ever increasing price of tuna. One of the most important factors in the cost of tuna fishing is the price of fuel which is likely to increase still further in the future. This prompted the comment that in terms of energy, tuna is already one of the most expensive forms of protein used for human consumption, and this should tend to discourage expansion.

The papers covering current assessment techniques give a very good picture of the state of the art methods that have been used for tuna and other fisheries with only minor modifications during the last twenty-five years.

Of particular relevance to tuna fisheries has been the production model which has appeared in a variety of forms. There is little uncertainty about the form this model takes for low values of fishing effort but in most applications there is a great deal of doubt about what happens as effort is increased past levels corresponding to the estimated maximum sustained yield. In the Atlantic billfish paper, however, there was some good evidence, despite the ever present difficulty of obtaining good data, or a nearly symetrical descending right hand portion of a production model at high fishing effort. For the Eastern Pacific yellowfin fishery the IATTC is attempting to answer the question of the behavior of the model by experimentally allowing yields which are higher than the model's estimated maximum sustained yield. In the paper on this fishery the effect of fluctuating year class strength's were discussed and it was shown that in a multi-age fishery these fluctuations tend to hide the long term changes that the production model predicts unless long sequences of data are looked at.

This effect was taken a step further with analysis of Atlantic bluefin tuna where up to 30 year classes are represented. In this paper cohort analysis was used to derive estimate of year class strength which were plotted as a stock-recruit curve which could have been interpreted as an extraordinary form of the Ricker type of model where at low stock size recruitment was many

times the recruitment at intermediate sizes; or alternatively could be explained as the effect of unexplained fluctuations in year class size of a very long lived species.

In the last two papers some of the current research into areas associated with stock assessment were described. In one there was a discussion of the effect of clustering of schools and the subsequent non-random searching on estimated encounter rates. This has a considerable impact on the use of catch-per-unit effort as a measure of abundance, and is an avenue of inquiry which has been badly neglected in the past. The final paper was a discussion of the relation between selected environmental variables and porpoise distribution. As well as being informative in its own right, this paper helped to remind the conference that we should never attempt to study a species in isolation from its environment and that the environment is composed of associated species as well as abiotic factors.

MANAGEMENT and the UNIT STOCK CONCEPT

Frank Alverson, Convenor

SUMMARY -- PANEL DISCUSSION: MANAGEMENT AND THE UNIT STOCK CONCEPT

Frank Alverson, Moderator

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The concept of management of a unit stock has been with us for many years. Some examples of unit stock management on an international (multination concept) basis are as follows:

Halibut Commission - U.S. and Canada - Halibut in the North Pacific
Salmon Commission - U.S. and Canada - Sockeye in Fraser River, etc.
Inter-American Tropical Tuna Commission - U.S., Costa Rica, Panama, Mexico, Canada, Japan, France and Nicaragua - Tropical tunas and baitfish in the eastern Pacific.
International Commission for Conservation of Atlantic Tunas - 18 nations - all tunas and billfishes in the Atlantic.
North Pacific Fur Seal Convention - U.S., Canada, Japan, Russia - Fur Seal.

Some examples of unit stocks which front two or more nations - and are primarily found within the 200-mile economic zones (FCZ) are as follows:

Anchovy - U.S./Mexico
Bonito - U.S./Mexico
White Sea Bass - U.S./Mexico
Yellowtail - U.S./Mexico
Mackerel - U.S./Mexico
Jack Mackerel - U.S./Mexico
Haddock - U.S./Canada
Scallops - U.S./Canada
Halibut - U.S./Canada
Salmon - U.S./Canada

Some examples of unit stocks which front more than two nations and are found in abundance, outside 200-mile economic zones are:

The billfishes
The tunas
The whales/large and small
Fur seals
Sea turtles
Oceanic sharks

You cannot have it both ways - manage an international stock on a unilateral basis and then try to manage the same or other stocks within the 200-mile zone of other countries.

Does a country that claims unilateral management of a portion of a unit stock, when it occurs within its 200 FCZ have any right to have an impact into what other countries have to say about the presence of the same stock off/in its 200-mile zone?

James Joseph

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If the objective of management is to maintain a stock of fish at levels that are capable of sustaining maximum yields such management must apply to all fisheries affecting that stock. Because tunas and billfishes are generally highly migratory, travelling through many juridical zones as well as on the high seas, their proper conservation calls for management measures which apply to these stocks throughout their range. Other species of fish, in addition to the tunas and billfishes, are also highly migratory. These other species must also be managed throughout their range for such management to be effective. As fisheries scientists, it is our responsibility to define the range, distribution and migrations of such stocks and to make recommendations for their management that are consistent with the biology and behavior of the fish which are the object of such management.

John Negroponte

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Negotiations between the United States and Mexico and Costa Rica for a new convention for management of eastern Pacific tunas were reviewed. The need for consideration of the unit stock management concept in the new convention was emphasized.

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(1) The Concept

The technical aspects have been explained by Dr. Joseph. The principle is clear that tuna species are highly migratory, and defined unit stocks thereof are best managed by international agreement.

The application of the concept results in management regulations affecting tuna fishermen. I will discuss this aspect rather than the technical aspects.

(2) Acceptance of International Regulation

The principle can be said to be nearly universally recognized by the scientific community. It is also recognized by the governments of the producers of the majority of tuna entering into world trade. It is recognized in the U.S. through the FCMA, the Fishermen's Protective Act and our Law of the Sea position.

(3) Non-Acceptance by Some in the U.S.

The FCMA fully recognizes the concept in the FCMA as it relates to tuna, but does not do so with respect to billfish, which is also highly migratory. This has caused interaction. Examples are:

The Western Pacific Fishery Management Council in 1977 proposed placing tuna under FCMA management provisions. This was a reaction to a NMFS proposal to place billfish in a category where it would be managed internationally.

The National Association for Marine Conservation this year formed the American Bluefin Committee, which proposes to put bluefin tuna under FCMA management. The genesis of this movement is the decision of sports fishing interests to move Japanese longliners outside 200 miles because of incidental hooking of billfish.

The Marine Fisheries Advisory Commitee (MAFAC) this year, as its major agenda item, proposed by sports fishing interests, discussed placing tuna under 200-mile management. Discussion on the merits of such a move led to dropping the subject.

The Gulf Fisheries Management Council this year recommended placing tuna under FCMA management as a means of helping negotiate a reduction in the number of longliners. This was a proposal from sport fishing interests.

Congressman McCloskey has proposed (HR.3852) to bring tuna under 200-mile management. This move is opposed by Chairman Breaux (Fisheries

Subcommittee) and by principal environmental organizations.

Thus, virtually all moves are based on the peculiar position of billfish. It is highly migratory and can best be managed internationally. Logically, it should be so managed. However, when FCMA was enacted there was no voting constituency which wanted this done and, therefore, billfish was left to FCMA management. Sports fishermen somehow consider that tuna should be similarly managed, even though their total Atlantic tuna catch in 1978 was about 70 tons out of a national total catch by commercial fishermen in all oceans of about 283,000 tons.

(4) Non-Acceptance Internationally

The history is reasonably well known and begins with the Truman proclamations on the Continental Shelf and on Fisheries, which was followed by the 200-mile declarations of Chile, Ecuador and Peru.

Currently, as Ambassador Negroponte has reported to you, the United States is renegotiating a new Eastern Pacific Conservation Treaty 33 years after the Truman proclamations and 29 years after IATTC began its work. New principles which recognize certain rights of resource adjacent nations will most likely be incorporated into a new treaty as a consequential breakthrough. The dilemna which all resource adjacent nations face is that in the development of a consequential, non-seasonal fishery, they must fish off the coast of neighboring nations. So each have-nation also becomes a have-not nation dependent upon international cooperation.

It is not a simple case of the United States against Latin America. Anyone looking at the situation recognizes the factor of interdependence when looking at migratory species -- a factor which brings us together.

(5) Tuna Fisheries Development by the United States

Tuna is the largest U.S. food fishery in both volume and value. Tuna people have been builders in terms of fisheries development throughout the world. While some regard a distant water fishery as made up of predators, history shows that wherever U.S. tuna people have gone some progress has ensued in that area.

Without detailing the particular enterprises, I believe you will be able to see or trace the effect of U.S. tuna people in or on tuna fisheries, as well as, in some cases, other fisheries development in these nations or areas: Canada, Mexico, Costa Rica, Nicaragua, Panama, Columbia, Ecuador, Peru and Chile, Venezuela, Puerto Rico (Commonwealth), Netherlands Antilles, Spain, France, Portugal, Senegal, Siera Leone, Ivory Coast, Ghana, South Africa, Aden (South Yemen), India, Indonesia, Philippines, South Korea, Papua New Guinea, Australia, New Zealand, American Samoa, Tahiti and the Trust Territory of the Pacific Islands.

I can give you a brief hisory of each should anyone ask.

(6) Tuna Development Under a 200-Mile or Similarly Restrictive World Regime

The United States fishery reportedly began in 1903. Following World War

II there was an essential rebirth of both the U.S. and Japanese fisheries as the great majority of U.S. vessels were taken by the Navy and once island warfare and the war began to lengthen, the Japanese fleet was out of action.

Where would tuna fishery development be today if following World War II, each nation had a 200-mile limit in place, embracing migratory species as a fit subject for ownership and management?

It is clear that the development given in the preceding section would not have taken place at the intensity and rate which actually occurred. Once restriction becomes the dominant policy, it affects the planning process and investments are likely to follow the same restrictive thinking.

(7) Is the Unit Concept Dead?

The concept is not contrived. That tunas (as well as some other species) are highly migratory is an established scientific fact. That they move in, out and over national sea boundaries without regard to jurisdictional or territorial claims is also a fact. That their conservation requires international cooperation is the logical, and generally supported, conclusion.

However, apart from the science, the concept often presents multi-faceted, political difficulty. Some, including some in the U.S., want to kill the concept by passing a law. Others understandably want to receive maximum benefit from the appearance of tunas in the zones which they claim. This is where we are today in treaty negotiations and new ground may be broken.

To answer the Chairman's question, the concept is not dead -- it gets bent out of shape on occasion.

(8) Uses of Scientific Information

Chairman Sakagawa asks the panelists to comment on uses of scientific information. This is a consideration of growing importance in making investment decisions once a fishery reaches reasonable maturity.

As a very young man, I can remember tuna fishermen discussing whether or not the tuna resources would hold up -- this was back in the middle 1930's. The fishery had been developed from California to the Galapagos by that time. It was not until 1951 that the fishery reached the area off northern Peru as the fishery and then the fleet expanded

The IATTC was born in 1949. It is a matter of importance to note that we know of no other major fishery where resource studies were begun long before there was a research problem. It was not until 1966 that the first quota on yellowfin was agreed upon for the area known as the CYRA. In the thirteen years since, the quota has often been increased -- never decreased -- as scientists enlarged their understanding and assessment of the population. The quota in 1966 was 79,300 tons of yellowfin and has reached as high as 210,000 tons on an optional basis since.

The scientific information became more useful as investments grew and financial institutions wanted more assessments of the resource.

The scientific information on tuna has not succeeded in developing a fishery. The judgements reached by the Tuna Commission, with respect to quotas and seasons, however, forced the extension of the fishery westward beyond the CYRA once the season closed, eastward as far as the coast of West Africa and southward to the Pacific islands.

Quota levels have risen. Dr. Joseph has given this history. I can recall when a decision was made to raise the quota to 140,000 tons of yellowfin annually for three years. The fishermen were warned that this could test and possibly adveresly affect the resource. These men who are by nature more optomistic than scientists (who are essentially over cautious) decided that it was their future that was at stake and decided there was at least that much tuna available without damaging the stock. The testing of the numbers began at that level. There was no problem as a result and later annual quotas were inceased.

So, between a group of able scientists and fully competent fishermen, this testing of numbers took place. There is only so much that can be calculated before proof is required. Testing numbers is important in any ocean. There are at least two results that can be expected: it keeps the spirit of enterprise and hope for increased results alive, and it lessens the possibly tyranny of the formally educated.

APPENDIX

30th TUNA CONFERENCE PARTICIPANTS

	NAME	AFFILIATION	LOCATION
1.	Louis Agard	Western Pacific Fishery Management Council	Honolulu, HI
2.	Robin Allen	Inter-American Tropical Tuna Commission	La Jolla, CA
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8.	Grant Beardsley	Southeast Fisheries Center	Miami, FL
9.	Noelle Beerman	Southwest Fisheries Center	La Jolla, CA
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18.	E.J. Conard, Jr.	Zapata Protein, Inc.	Houston, TX
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20.	Brian Culver	Washington Dept. of Fisheries	Montesano, WA
21.	Richard Evans	Southwest Fisheries Center	La Jolla, CA
22.	Augusto Felando	American Tunaboat Association	San Diego, CA
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25.	Virginia Flagg	Dept. of Economics, San Diego State Univ.	San Diego, CA
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32.	Ann Hockberg	Oregon State University	Corvallis, OR

	NAME	AFFILIATION	LOCATION
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38.	Nick Lamont	Star Kist Foods	San Pedro, CA
39.	R. Michael Laurs	Southwest Fisheries Center	La Jolla, CA
40.	David Mackett	Southwest Fisheries Center	La Jolla, CA
41.	Michael McGowen	Bumble Bee Seafoods	San Diego, CA
42.	Stan Moore	Southwest Fisheries Center	La Jolla, CA
43.	Arturo Muhlia	Inter-American Tropical Tuna Commission	La Jolla, CA
44.	John Negroponte	Department of State, U.S.	Washington, DC
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